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## Chapter 5

# CHARACTERIZATION OF MULTIPLE CHLORINATED SOLVENT PLUMES DUE TO THE IMPACT OF TCE SCREENING LEVEL REDUCTION

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## ABSTRACT

The reduction in the trichloroethylene (TCE) vapor phase screening level by USEPA in 2004 prompted a re-evaluation of groundwater contaminant source areas, transport mechanisms, and commingling of multiple CVOC plumes within a complex river basin. A USEPA Administrative Order on Consent (AOC) dictated that the former owner of the facility investigate and perform residential and commercial vapor phase removal action to achieve compliance with revised indoor air and subsurface action levels. The AOC did not differentiate contaminant source areas, transport, or commingled contaminants. In response, a comprehensive re-evaluation of the river basin hydrogeology and groundwater CVOC distribution was completed to facilitate demarcation of the AOC vapor phase removal action boundary and to minimize cleanup of contaminants not attributable to the facility. In 2007, an integrated investigation and review of remediation reports filed with state regulators, USGS hydrogeologic reports, and historical groundwater elevation data was conducted. The data were evaluated to identify additional CVOC source areas, map known CVOC plumes, establish groundwater flow transport pathways, and determine the potential for commingled CVOC plumes. Understanding the complex groundwater flow regime, strongly influenced by river stages, flood control structures, municipal well field production, and engineered recharge basins, was critical to resolving the migration pathway of multiple CVOC plumes. All data collected was compiled into a series of CVOC overlay maps to provide a working river basin model of CVOC distribution and migration based on groundwater flow. The distribution of CVOC source areas results in numerous instances of CVOCs plumes becoming commingled due to the groundwater flow patterns. As a result, the former owner recommended the reduction of the AOC vapor phase removal action boundary area by over 60%, thus limiting the action area to immediately downgradient of the facility based on groundwater flow.

Keywords: groundwater, chlorinated solvents, investigation, multiple plumes, commingled plumes.

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## 1. INTRODUCTION

The reduction in the trichloroethene (TCE) vapor phase screening level by USEPA in 2004 prompted a re-evaluation of groundwater contaminant source areas, transport mechanisms, and commingling of multiple chlorinated volatile organic compound (CVOC) plumes within a complex river basin. The groundwater TCE concentrations measured during a voluntary plume characterization downgradient of the facility (performed in 2003) met the screening level vapor phase risk criteria for the protection of human health. This voluntary off-site plume characterization identified several potential CVOC source areas in the river basin that are not related to the subject facility or to migration of contaminants from the facility.

Following the 2004 change in the vapor phase screening level, the USEPA issued an AOC dictating that the former owner of the facility investigate and perform residential and commercial vapor phase removal action to achieve compliance with the revised indoor air and sub-slab action levels. The AOC did not take into account the various known and suspected source areas in the immediate area, or commingled contaminant plumes. In response, a comprehensive re-evaluation of the river basin hydrogeology and groundwater CVOC distribution was completed to refine the demarcation of the AOC vapor phase removal action boundary and minimize cleanup of vapor phase contaminants not attributable to the facility.

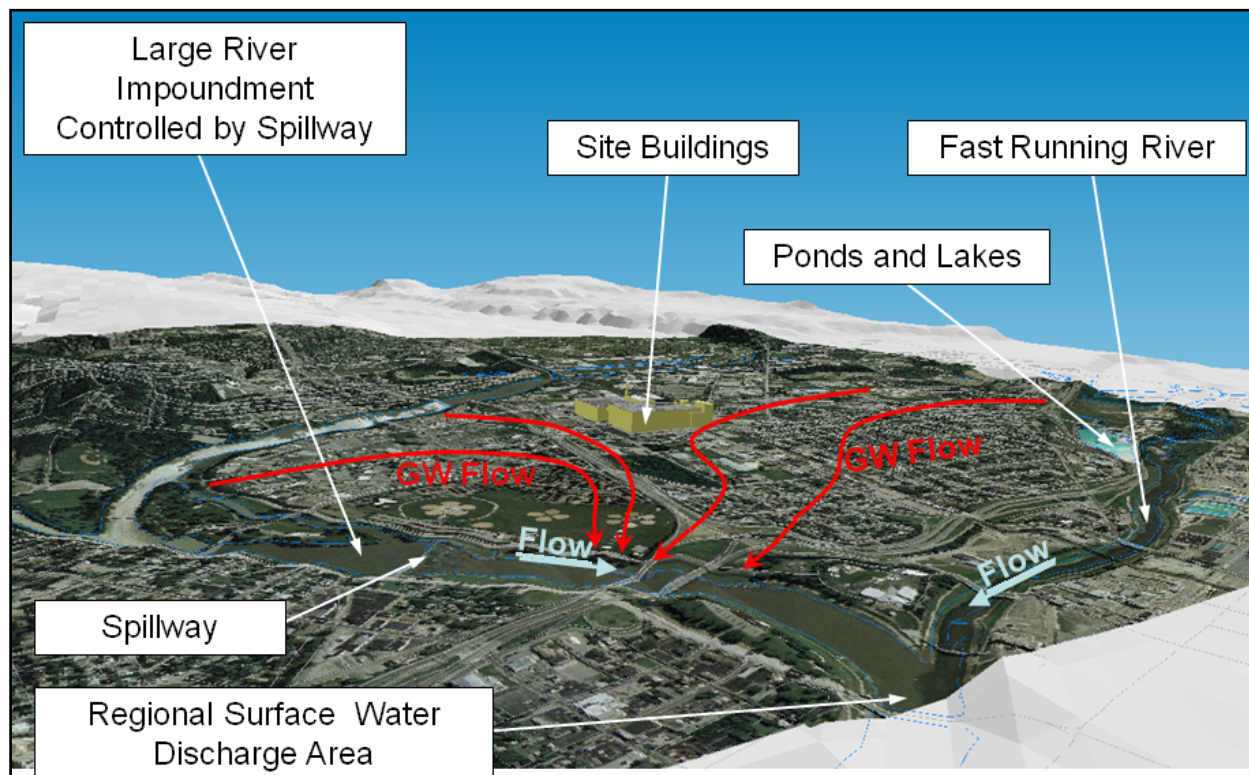


Figure 1. Site groundwater flow patterns and hydraulic controls.

The complex surface water system that controls groundwater flow in the basin is presented on Figure 1. The site is located on a buried glacial valley that is surrounded by rivers on three sides. River stage to the north and west is controlled by a spillway. This river is a losing river that recharges the aquifer below the site and strongly impacts flow in the basin. Below the spillway, the river gains and is a discharge point for the aquifer.

Another river is located on the south side of the facility. This river is fast flowing because of its elevation drop from east to west, and does not have spillways or other flood control structures in the vicinity of the site. The influence this river has on the aquifer within the basin is highly dependent on precipitation and river stage. The confluence of these two rivers is located southwest of the facility and acts as a regional surface water discharge area.

The buried glacial aquifer below the site is prolific and water levels within the aquifer change rapidly because of the presence of the two rivers, the spillway on the northern river, and the configuration of recharge / discharge areas.

## **1.1 2003 Characterization of Multiple Plumes**

The voluntary plume characterization completed in 2003 established the groundwater flow regime downgradient of the facility and identified numerous suspected potential contaminant source areas. Understanding the complex groundwater flow regime in a sand and gravel glacial valley fill aquifer, strongly influenced by river stages, flood control structures, municipal well field production, and engineered recharge basins was critical to resolving the migration pathway of the multiple CVOC plumes.

In addition to the permanent groundwater monitoring network, the 2003 investigation included 50 Geoprobe membrane interface probe / electrical conductivity borings to evaluate the stratigraphy and vertical distribution of CVOCs prior to collecting two groundwater grab samples from each location. A total of 30 temporary water table wells were also installed. Figure 2 shows the groundwater flow and contaminant characterization as understood after the 2003 investigation. In Figure 2's perspective (looking to the northwest), it is clear that the losing nature of the river above the spillway causes groundwater flow, and associated dissolved-phase CVOCs, to migrate away from the river and then toward the aquifer's discharge area below the spillway.

The contaminant plume depicted in Figure 2 is trichloroethene (TCE), with concentrations cropped at 50 parts per billion (ppb). TCE and tetrachloroethene (PCE) are the primary contaminants of concern at the site.

Figure 3 presents the site, as understood after the 2003 groundwater characterization, from an aerial perspective and includes 1,1,1-trichloroethane (TCA) in addition to PCE and TCE. Concentrations of CVOCs in Figure 3 are cropped at 5 ppb. The aquifer's potentiometric surface is also shown (red contours). The manufacturing buildings on-site are shown in gray.

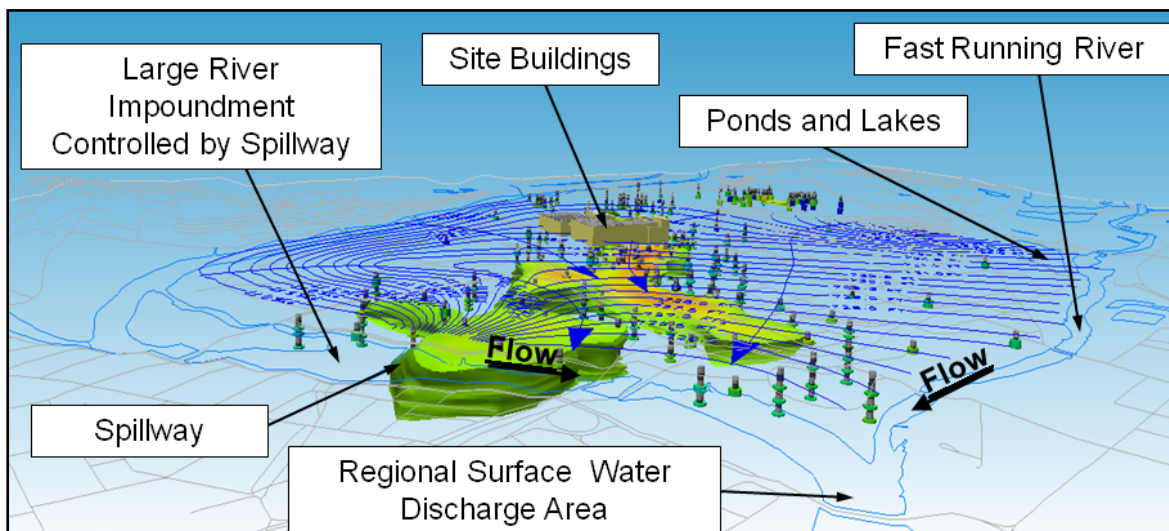


Figure 2. Pre-characterization groundwater flow with TCE > 50 ppb.

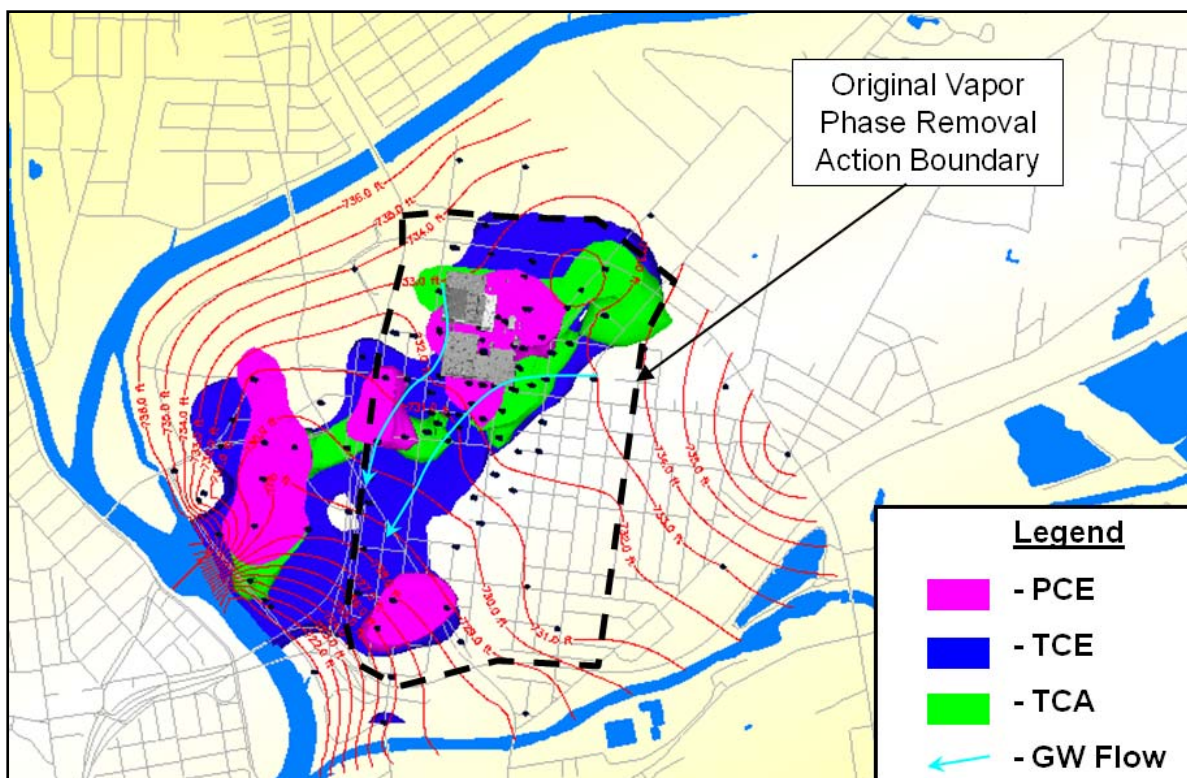


Figure 3. Original vapor-phase removal action boundary, concentration > 5 ppb.

Comparison of the groundwater flow pattern in the basin between the two rivers and observed contaminant distributions for the three parent CVOCs shown in Figure 3, strongly suggests the



presence of additional contaminant sources areas. The presence of the impoundment's spillway as the groundwater discharge point controls the flow and causes contaminants from the various suspected source areas to become commingled as they migrate toward the discharge area. It is also noted that upgradient of the facility (to the northeast), TCE and TCA are migrating onto the site; presumably from other off-site source areas. Upgradient areas were not included in the 2003 characterization.

The AOC's original vapor phase removal action boundary is also presented on Figure 3. The boundary includes areas cross gradient from the facility and areas of the plume clearly influenced by other sources. The boundary also includes areas upgradient of the facility where impacts from other source areas migrate on to the site and commingle with impacts from past site activities. Finally, the boundary also includes a larger area to the south of the facility that is (a) not known to be impacted and (b) not downgradient of the facility, but would need to be investigated under the terms of the AOC.

## **2. MATERIALS AND METHODS**

### **A. 2007 COMPREHENSIVE RE-EVALUATION**

Upon receipt of the AOC, a comprehensive re-evaluation of CVOC contaminant distribution, groundwater flow, and potential sources areas in the basin was undertaken. The re-evaluation in 2007 integrated hydraulic data from USGS Hydrogeologic reports, investigation and remediation reports filed with the state environmental agency, and historical groundwater elevation data from the site proper as well as data from other sites in the basin.

To obtain information on other potential sites in the basin, a comprehensive search for other contaminated sites was conducted using Freedom of Information Act (FOIA) file searches. The effort revealed that several sites, with current or previous remediation systems, are located in the area of the manufacturing facility. The location of the other sites, and data on their associated groundwater impacts, coincided with the suspected source areas from the 2003 site-wide plume characterization investigation.

The focus area for the 2007 re-evaluation was expanded to include upgradient areas. Upgradient areas were identified and targeted for research based on the groundwater flow characterization completed in 2003. This effort resulted in the identification of several upgradient contaminant source areas and their resulting CVOC plumes. In addition, a joint, single day, collection of groundwater elevations measurements was completed. Representatives from the state agency, the municipality, and others participated in the effort. Water levels from existing municipal well head protection monitoring wells, surface water measurements from staff gauges, and water levels from numerous groundwater monitoring wells were collected during the effort to provide a comprehensive picture of the groundwater flow regime for the basin in the area of the facility.

The data from the 2007 re-evaluation, including data from the joint water level measurement effort, were evaluated to identify additional CVOC source areas, map known CVOC plumes, establish groundwater flow transport pathways, and determine the potential for commingled CVOC plumes. The data collected were compiled into a series of CVOC and groundwater flow overlay maps to provide a working model of CVOC distribution and migration based on groundwater flow within the glacial valley aquifer.

This evaluation revealed numerous contaminant plumes from multiple source areas in the area of the site. The off-site source areas were located upgradient, side gradient, and down gradient of the facility. Depending on the location of the individual source area, resulting groundwater impacts were observed to migrate with the regional groundwater flow pattern. The locations of the source areas and the groundwater flow pattern for the basin result in varying initial flow directions at the individual source areas, but all migration of dissolved-phase CVOCs is eventually toward the regional groundwater discharge area located below the impoundment spillway.

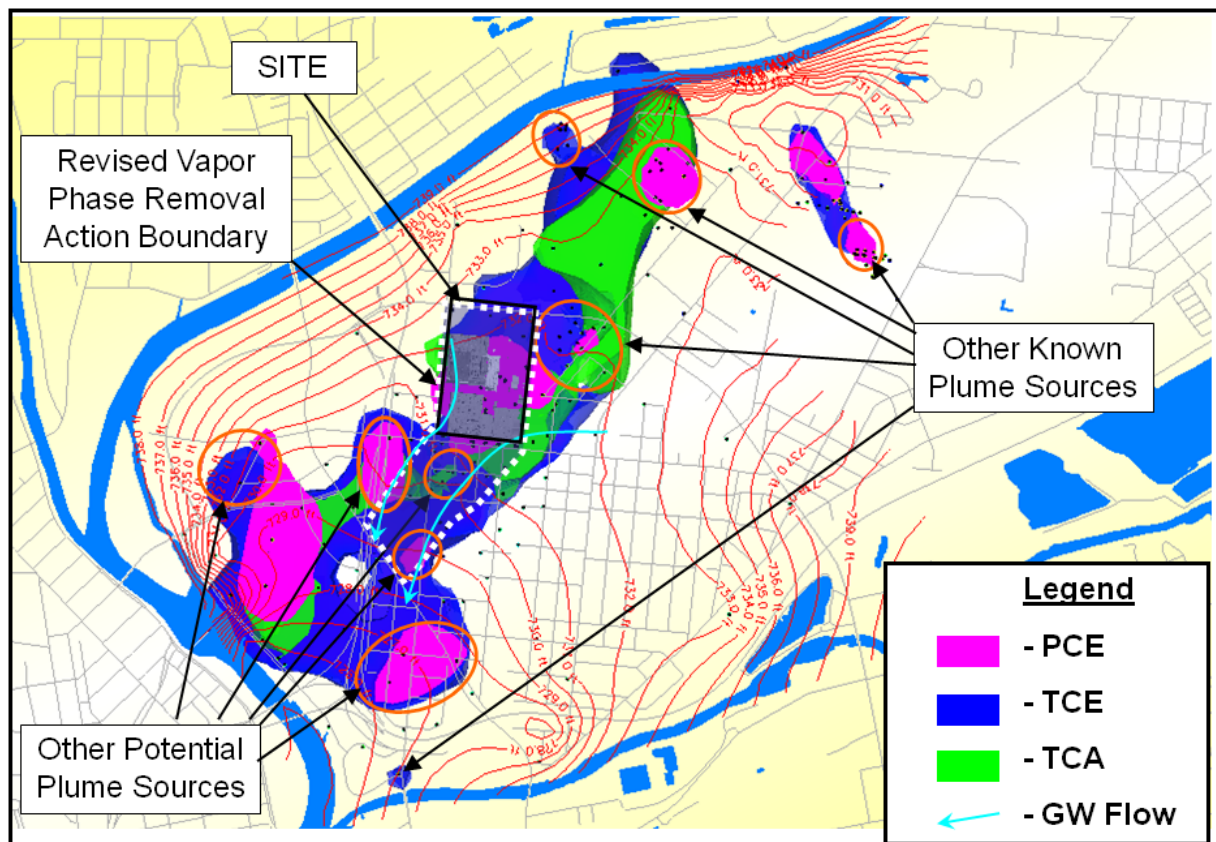


Figure 4. Revised vapor-phase removal action boundary, concentration > 5 ppb.

The result of this groundwater flow/contaminant migration pattern is that CVOC plumes from the individual source area become progressively more commingled as the contaminants near the discharge area. In addition, the 2007 re-evaluation demonstrated that (a) resolution of

impacts from individual CVOC sources became more complicated as contribution from more sources joined the overall plume, and (b) as the plumes neared the groundwater discharge area, resolution of impacts from individual source areas in the basin was not possible (or at least would become exceedingly difficult and highly speculative).

The CVOC contaminant distribution and groundwater / surface water flow hydraulic relationships resulting from the 2007 re-evaluation are presented in Figure 4. As in Figure 3, PCE, TCE, and TCA are shown on the drawing with concentrations truncated at 5 ppb. Comparison of Figures 3 and 4 shows the additional resolution that was added upgradient of the site property. Known source areas and other suspected potential source areas are also identified on the figure.

Figure 4 also shows the revised vapor phase removal action boundary proposed for the site. The revised vapor phase removal action boundary was proposed to focus site resources on areas clearly impacted by the facility and not on those areas for which the facility is not responsible. In addition, the revised boundary is truncated in the downgradient direction (i.e., southwest of the site toward the impoundment spillway) because of the commingling of CVOC impacts from the various known source areas located south and southwest of the facility.

## **2.1 Data Analysis**

The groundwater sample data were compiled by assigning State Plane Coordinates, well casing elevation, screen interval elevation and groundwater chemistry data into an Access database and evaluated utilizing 3-dimensional kriging software. Three known source chlorinated solvent contaminants found at the site, TCE, PCE, and TCA were selected as the primary contaminants for evaluation in the aquifer and were used to identify the multiple contaminant plumes.

The surface water level measurements and river gradient characteristics were compiled with data collected from USGS topographic maps for the surrounding rivers, impoundments, and infiltration ponds. This data was integrated with the groundwater elevation data across the basin to generate a comprehensive groundwater/surface water contour map and flow direction. The groundwater flow data was overlain on the contaminant plume distribution data to evaluate the contaminant plume source areas, migration pathways, commingling, and the discharge area. The evaluation demonstrated that CVOC plume migration mirrored the predominant groundwater flow patterns of the basin aquifer.

To visualize the extent of the CVOC contaminants, the concentrations were cropped at 5 ppb to match the Maximum Concentration Limit (MCL) of TCE, the primary chemical of concern with respect to indoor air vapor intrusion. To identify more recent chlorinated solvent impacts, TCA was also mapped because it replaced the use of TCE in the late 70's. The value for TCA was cropped at the same value of TCE, rather than the MCL of 70 ug/L for TCA. This analysis revealed several other known and potential contaminant source areas based on contaminant distribution with respect to the identified groundwater flow direction. When concentrations were cropped at values higher than 50 ug/L, the detection of the chemicals of concern in the other source areas tends to remain as shown on Figure 5.



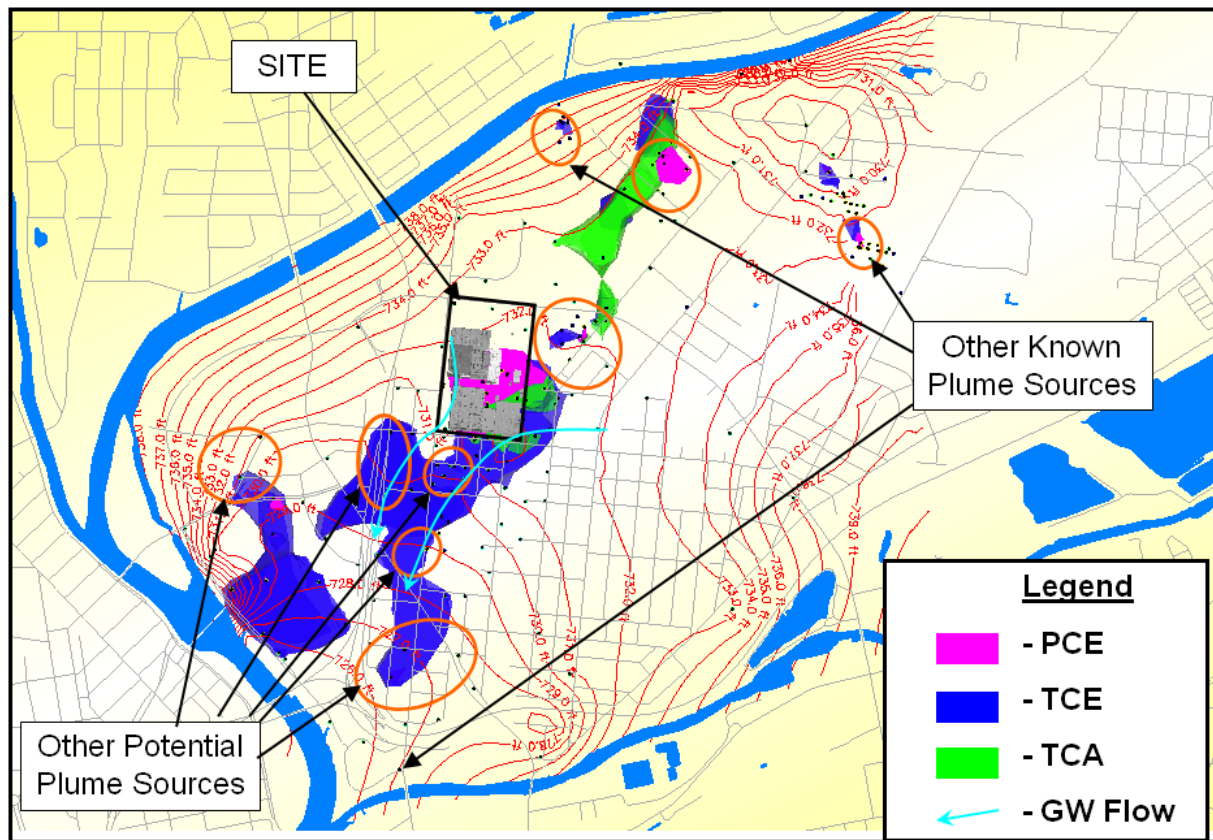


Figure 5. Historical data plume map with expanded data, concentration >50 ppb

### 3. RESULTS AND DISCUSION

#### 3.1 2007 – 2008 Confirmation Field Effort

To confirm the findings of the 2007 comprehensive re-evaluation of CVOC contaminants and groundwater flow, additional investigation was performed in 2007 and 2008 to further refine the contaminant distribution and groundwater flow downgradient of the facility. The results of the confirmation field effort include the following conclusions.

The groundwater flow direction remains relatively constant, even though river stage fluctuation can be significant. This finding is based on several measurement events and the analysis of data from dedicated transducers, which continuously measures water levels at selected points within the basin. The response of the aquifer to upward changes in river stage upstream of the impoundment spillway was observed to occur over a very short period of time.

Additional permanent monitoring well nests and temporary water table wells were installed to the south/southwest of the facility during the 2007-2008 confirmation field effort. Laboratory

analytical data and water level measurements from these newly installed wells provided further resolution and confirmation of groundwater flow near the discharge point, location of the various plumes downgradient of the facility, and confirmed an additional CVOC source area.

The 2007 – 2008 confirmation field effort also provided additional resolution to groundwater flow patterns south of the facility along the fast-flowing river located on the south boundary of the basin. During high river stage, the influence of groundwater extraction to prevent flooding of a street underpass located at the southern end of the basin becomes more prevalent. The presence of this periodic groundwater extraction point was not known during the 2003 characterization, and was observed, but not understood during the 2007 comprehensive re-evaluation.

Two additional drawings, Figures 6 and 7, are presented below. These drawings were prepared using the site database augmented with laboratory analytical data from the most recent sampling rounds completed in 2008, and use the most recent water table surface. Figure 6 shows the expanded basin area, including areas upgradient of the site, with the concentrations of the PCE, TCE, and TCA cropped at 5 ppb. Figure 7 shows the same area with CVOC concentrations cropped at 50 ppb. Comparison of Figures 6 and 7 indicates that the identified CVOC source areas remain consistent at both the 5 and the 50 ppb concentrations range. Using the additional groundwater sampling data from the 2007 – 2008 confirmation field event, the southern portion of the basin is better defined. Contaminant source areas that were previously not well understood have been resolved due to the addition of several wells in this vicinity.

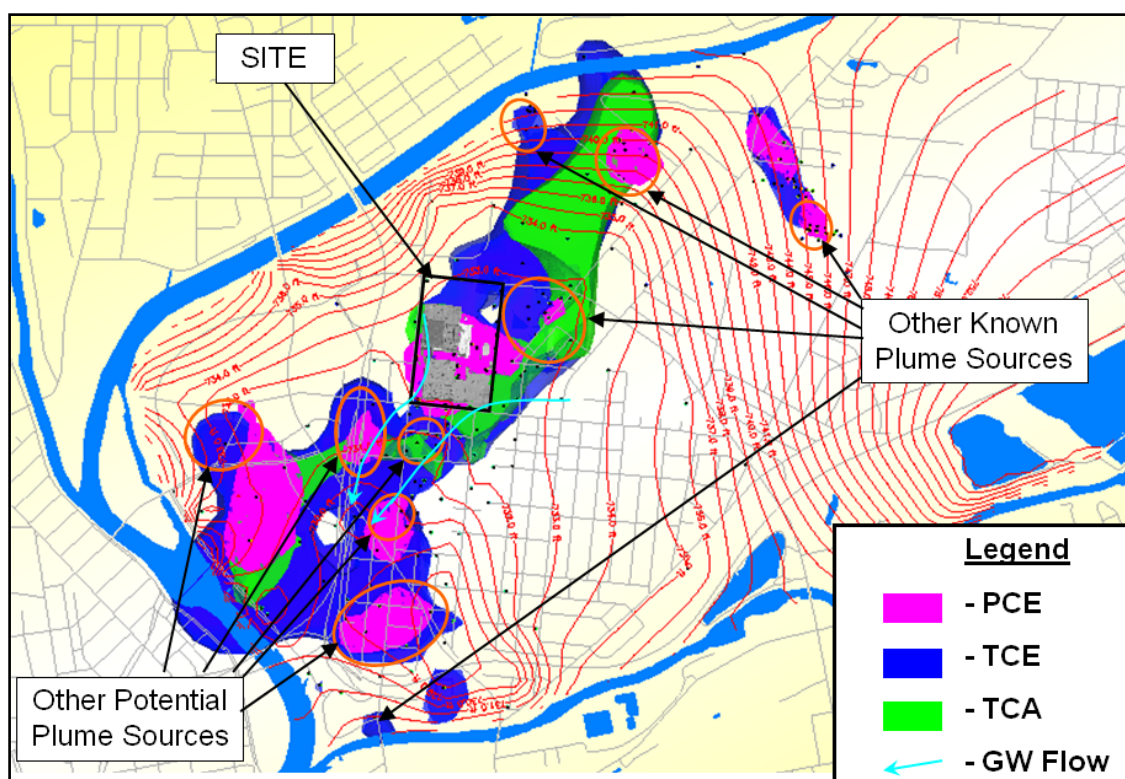


Figure 6. 2008 data plume map with expanded area, concentrations > 5 ppb.

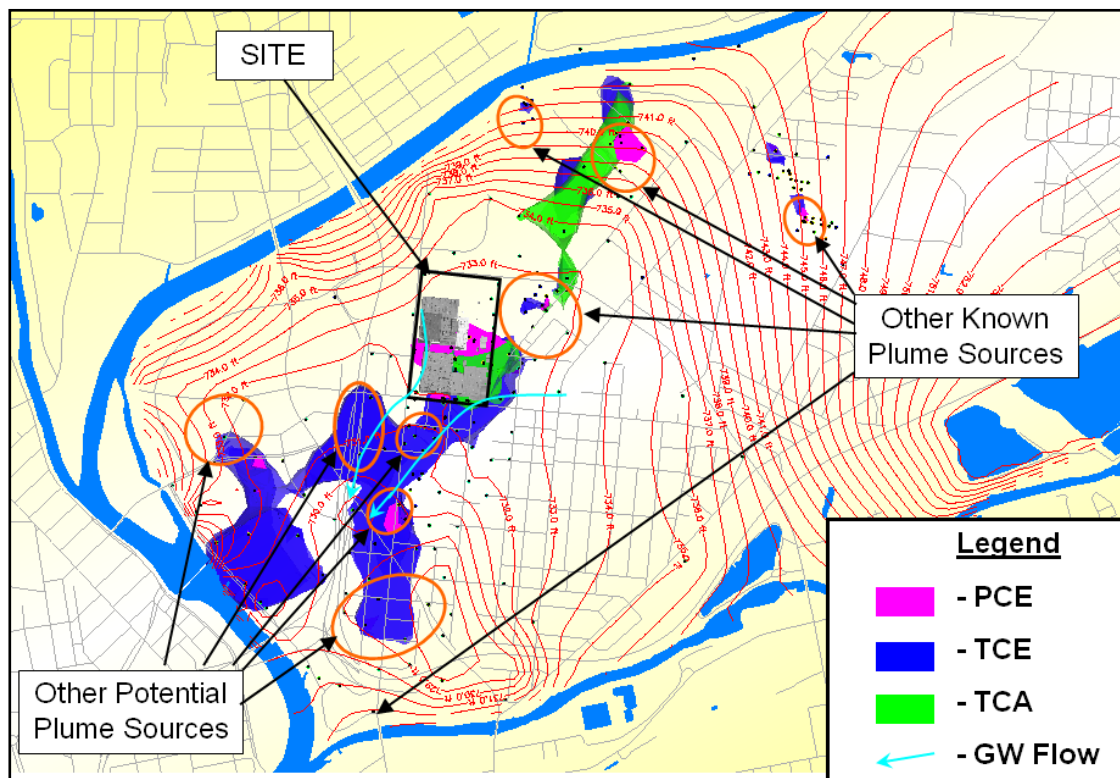


Figure 7. 2008 data plume map with expanded area, concentrations > 50 ppb.

#### 4. CONCLUSIONS

The reduction in the trichloroethylene (TCE) vapor phase screening level by USEPA in 2004 prompted a re-evaluation of groundwater contaminant source areas, transport mechanisms, and commingling of multiple CVOC plumes within this complex river basin. A USEPA Administrative Order on Consent (AOC) dictated that the former owner of the facility investigate and perform residential and commercial vapor phase removal action to achieve compliance with revised indoor air and subslab action levels. In response to these actions by the USEPA, a basin-wide re-evaluation was completed.

Groundwater impacts at the site, and downgradient of the site, were initially characterized during a voluntary groundwater characterization in 2003. At that time, the presence of other contaminant plumes originating from off-site sources was suspected, but not confirmed. Off-site sources were also suspected upgradient of the facility as well as downgradient and cross gradient. During the 2007 comprehensive re-evaluation, additional data was gathered from a variety of sources to expand and refine the understanding of groundwater flow within the basin and to document the presence of other source areas within the basin. This re-evaluation effort, in combination with field data collected during the 2003 plume characterization, identified areas of commingled groundwater CVOC plumes. Commingled areas were identified upgradient of the site, below the site property itself, and downgradient of the site.

A 2007 – 2008 confirmation field program was completed following the 2007 comprehensive re-evaluation. The field effort added significant resolution and confirmation to the 2007 re-evaluation findings. The confirmation field effort contributed to the understanding of off-site source areas, groundwater flow near the primary discharge area, and the identification of a periodic groundwater discharge area in the southern portion of the basin.

Based on the findings of the 2007 re-evaluation and the 2007 – 2008 confirmation field effort, the former owner of the facility proposed a revised AOC area in which residential and commercial vapor-phase removal actions would be completed. The revised AOC area was designed to focus resources on those areas impacted by the facility. The proposed AOC removal action boundary is approximately 60% smaller than the original area.